Developing Sub-Domain Verification Methods using GIS Tools

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Benefits of accurate weather forecasting

- Battle commanders have enhanced situational awareness.
- Commanders and Soldiers can undertake weather risk mitigation.

The Allies surprised the Germans on D-Day because they had more accurate weather forecasting.

Model Information

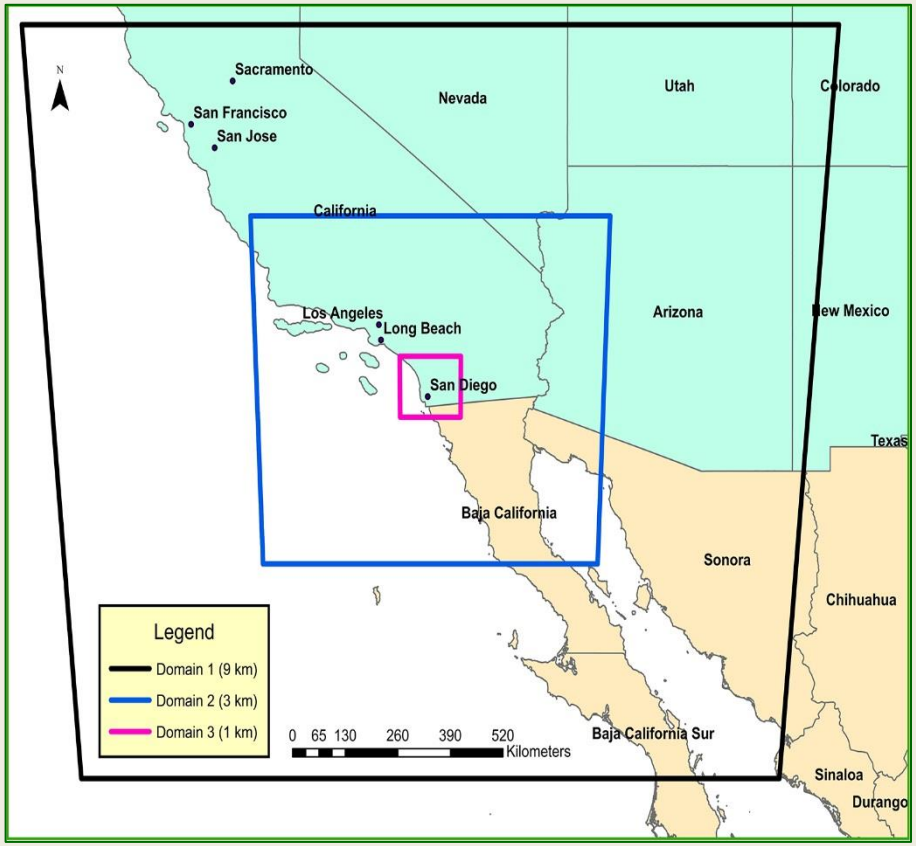
WRF (Weather Research and Forecasting)

Numerical weather prediction model developed and maintained by the National Center for Atmospheric Research (NCAR).

Parameterizations to represent unresolved atmospheric physics that create weather.

Triple nest with a grid spacing of 9/3/1-km.

WRF Domain Configuration



Importing WRF Forecast into GIS

Before ArcMap Version 10.3, WRF forecasts could not be imported directly into GIS

- WRF NetCDF output has staggered wind fields.
- WRF GRIB output was not a supported GIS file format.
- Version 10.3 can now import Gridded Binary (GRIB) files directly using Add Data!

When importing data into GIS, it is necessary to assign a datum and projection

- WRF assumes a perfect sphere (no datum) and Lambert Conic Conformal.
- Assigned NAD1983 datum/GCS North American projection to WRF forecast rasters.

WRF Forecast Verification

Compared WRF forecasts to observations

- NCAR Model Evaluation Tools (MET) interpolate WRF value to weather stations.
- Imported MET output text file into GIS using Create Feature Class/From XY table tool in ArcCatalog.
- Did considerable research to find the correct projection and datum for the WRF forecast-observation matched pair data.

Compared MET interpolation to GIS interpolation

- Imported WRF forecast rasters into GIS using the Add Data tool.
- Reprojected WRF forecast rasters using the Project Raster tool.
- Used Extract Values to Point tool to interpolate the value of the reprojected forecast at each point.

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WRF Verification Results

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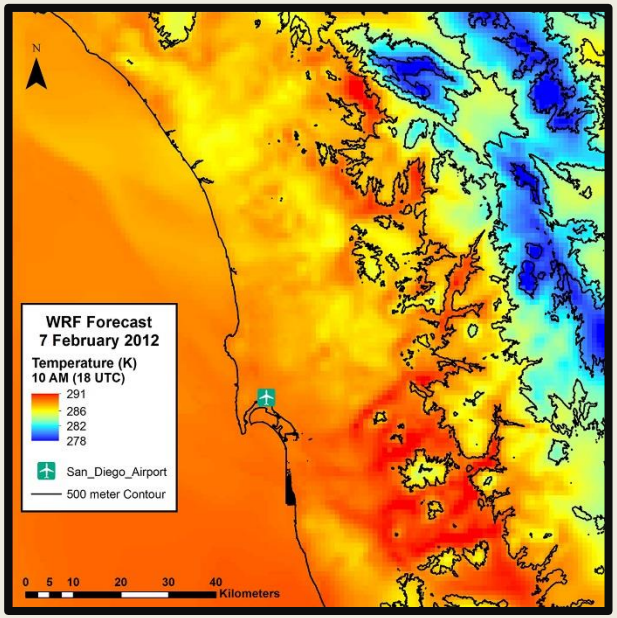
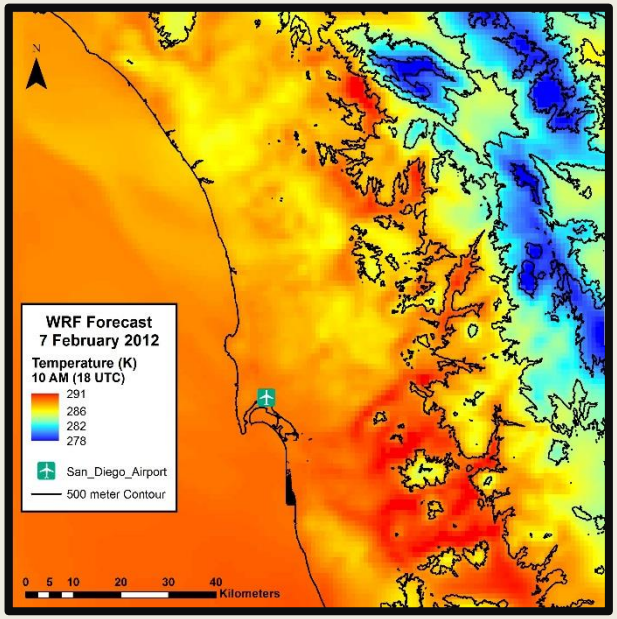
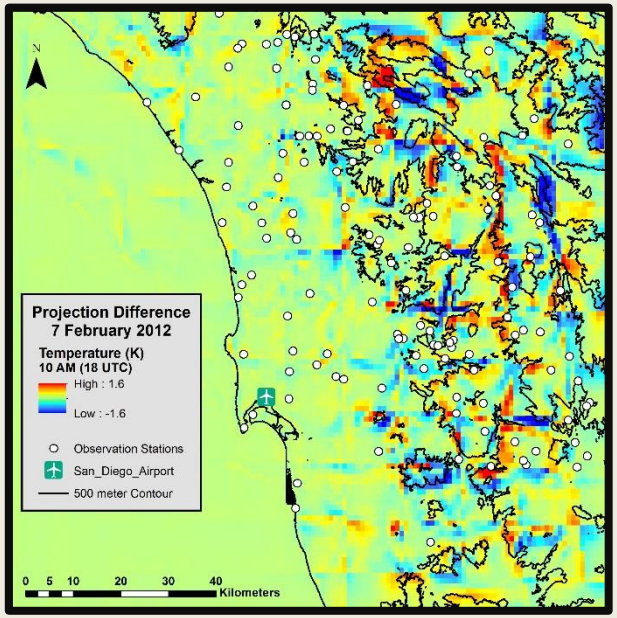


Original WRF forecast
Lambert Conic Conformal
No datum



WRF forecast reprojected
GCS North America 1983
NAD83



Difference raster
Reprojected minus original

- MET uses original WRF raster to interpolate forecast to stations.
- This study used the reprojected raster to interpolate forecast values.
- For most hours of 5 day case study, the difference between MET interpolation and GIS interpolation is not statistically significant.

Investigate Model Bias Variability

- Developed terrain variables to explain the variability of model bias.
- Used the Exploratory Regression Tool in the Spatial Statistics toolbox.

Terrain Variable	GIS Tool	Data Source
Elevation	Add Rasters to Mosaic Dataset (Data Management)	MADIS[b]
Latitude	Create Feature Class/From XY Table	MADIS[b]
Longitude	Create Feature Class/From XY Table	MADIS[b]
WRF Elevation Difference	Add Data	WRF GRIB output and USGS DEM
Slope	Slope (3D Analyst)	USGS DEM
Coast Distance	Near (Analysis)	CEC[c] Coastline
NDVI[a]	Extract Subset (Data management)	MODIS Terra satellite

[a]Normalized Difference Vegetation Index.
[b]Meteorological Assimilation Data Ingest System, weather observations source.
[c]Commission for Environmental Cooperation.

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Candidate Explanatory Variables

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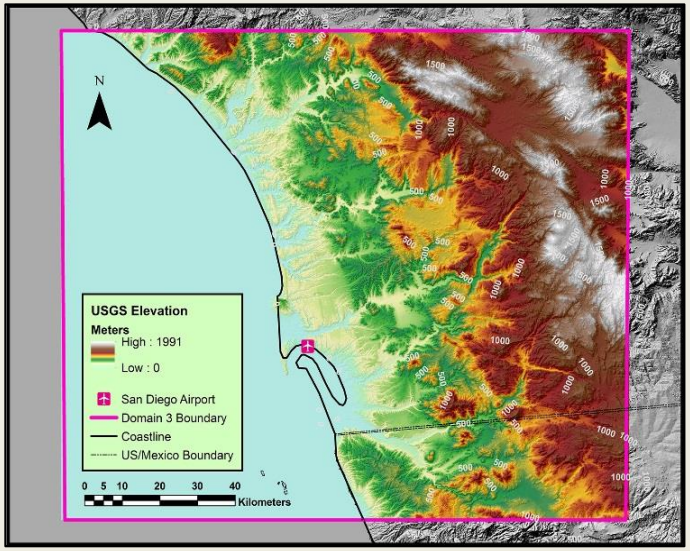
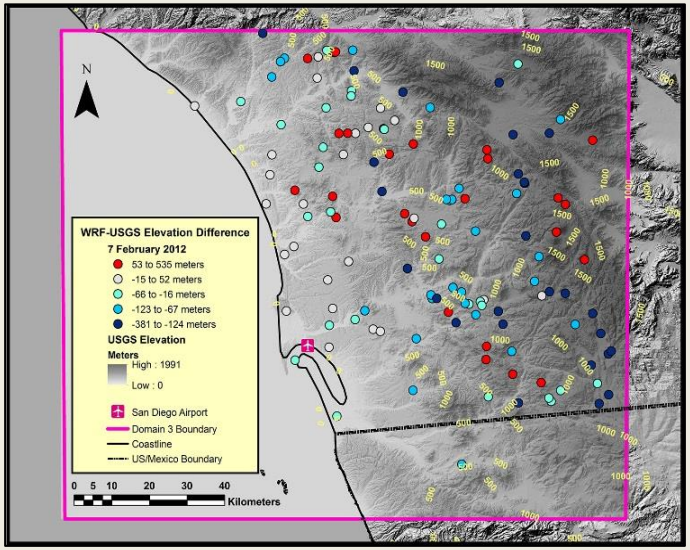
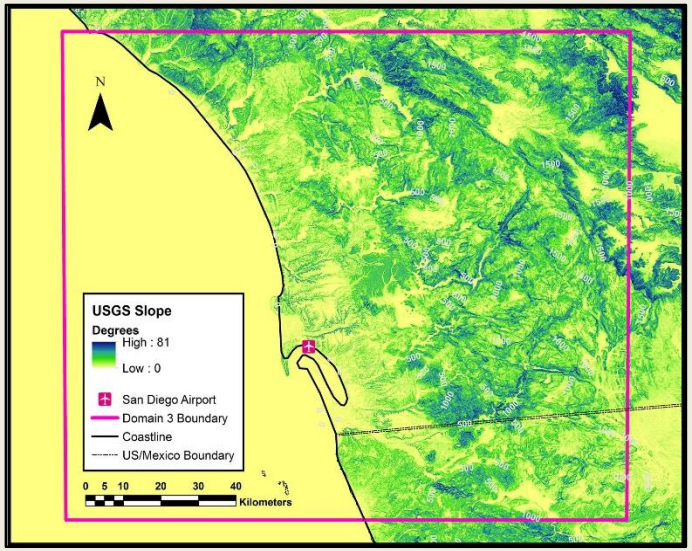
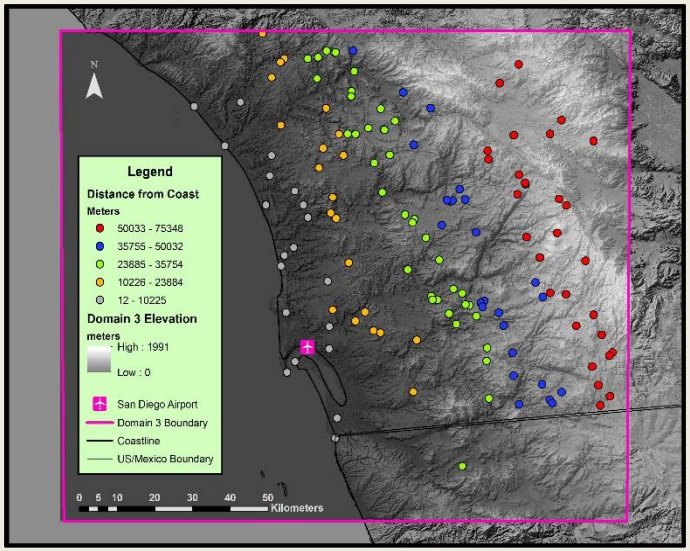




WRF Terrain, 1 km grid size (left top)

MADIS Station-WRF Elevation Difference (right top)





Slope (left bottom)

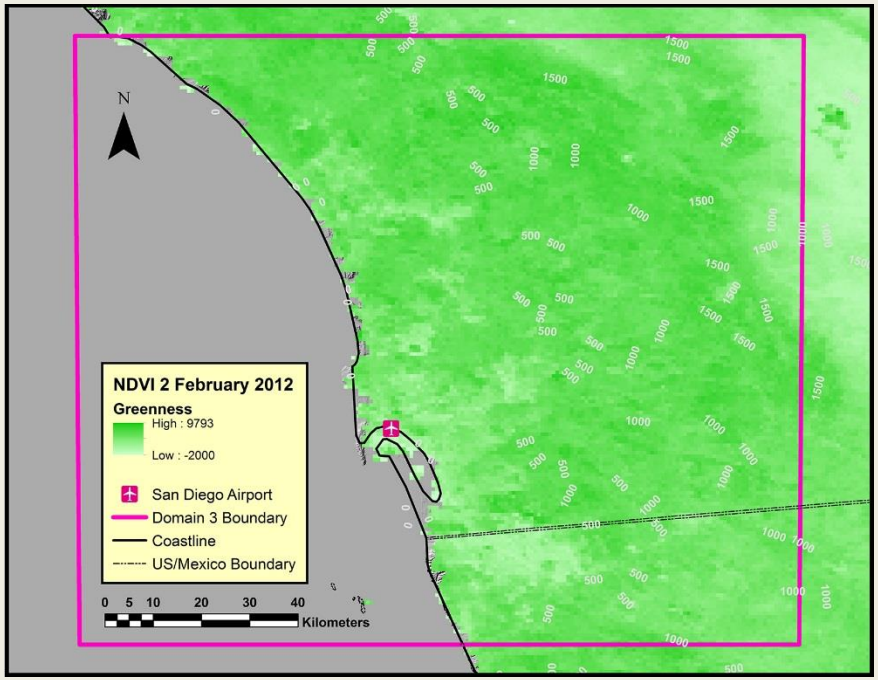
Coast Distance (right bottom)

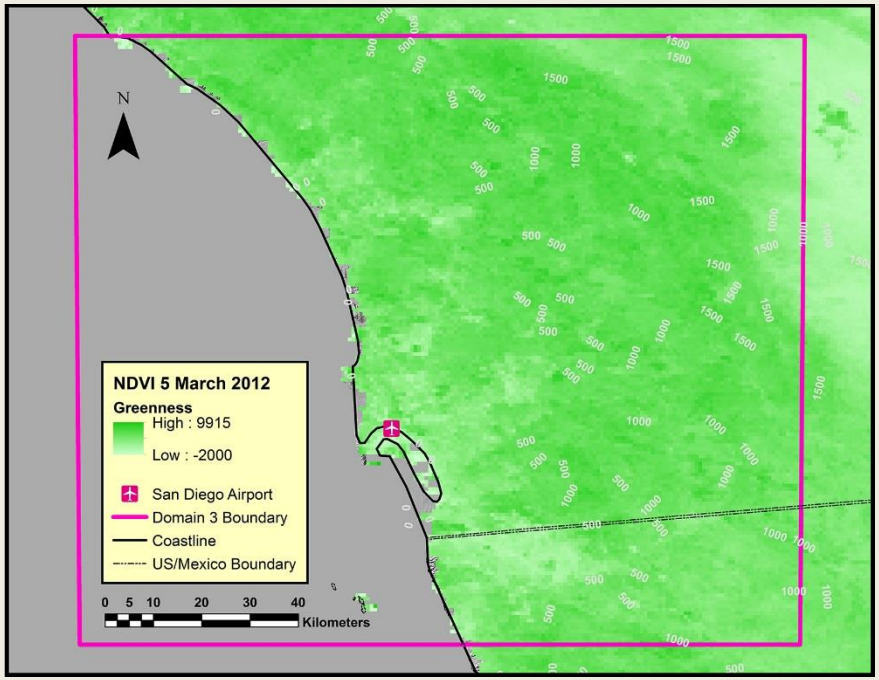
NDVI Terrain Variable

NDVI is a measure of greenness

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

Where NIR is near infrared radiation and RED is red visible radiation.





Each satellite image is a 16 day composite.

Correlation and Model Bias

Eliminated coast distance and longitude from analysis

- North-south coastline means longitude duplicates coast distance information.
- Strong 1:1 relationship between elevation and coast distance.

Preliminary conclusions

- For some hours, one regression model for the entire domain may not be appropriate.
- Elevation is an important explanatory variable.
- All five explanatory variables are significant to model bias at least for some hours.
- More explanatory variables are needed.

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2-7-12 EBK Model Bias Surfaces

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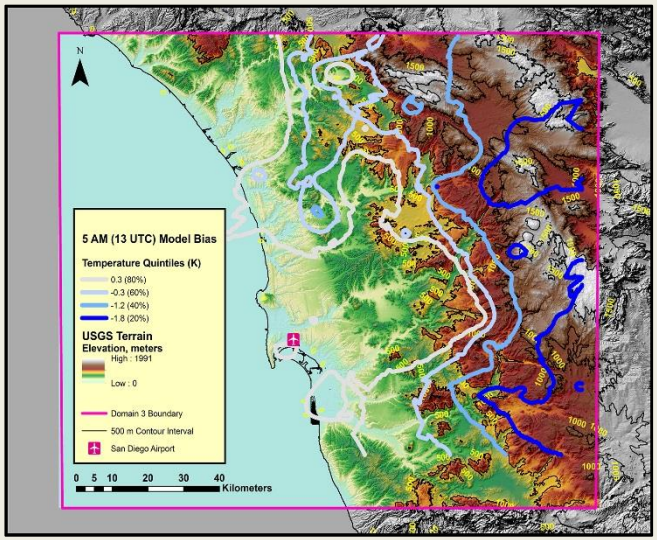
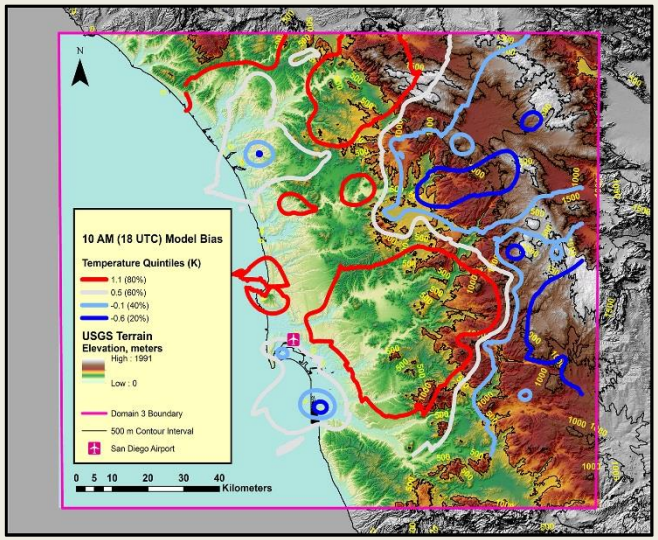
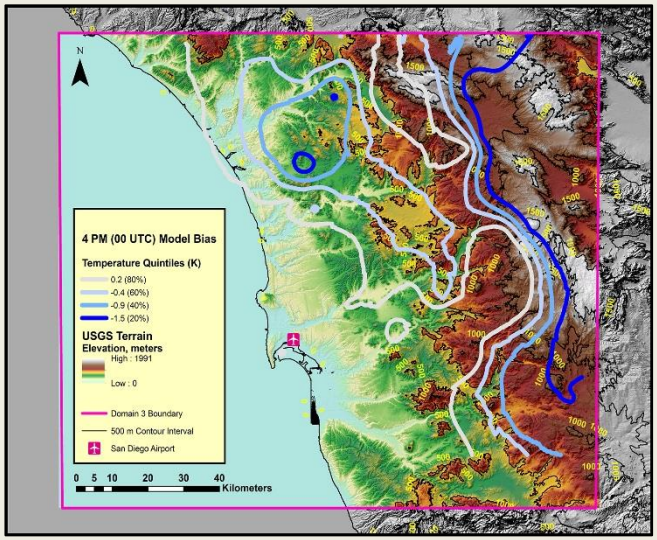
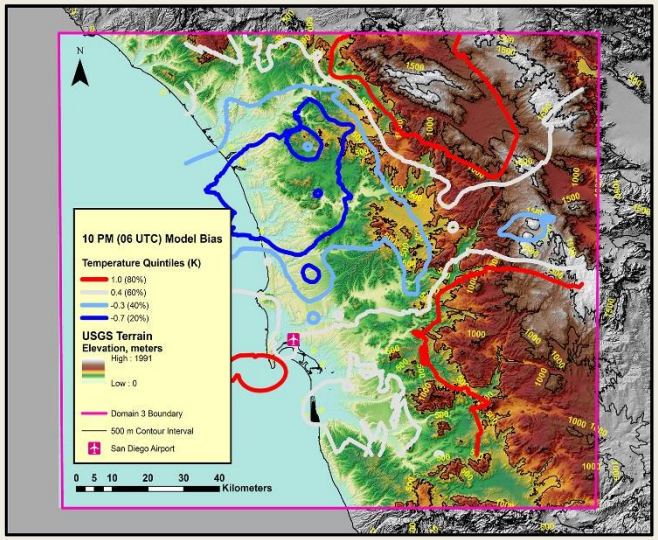
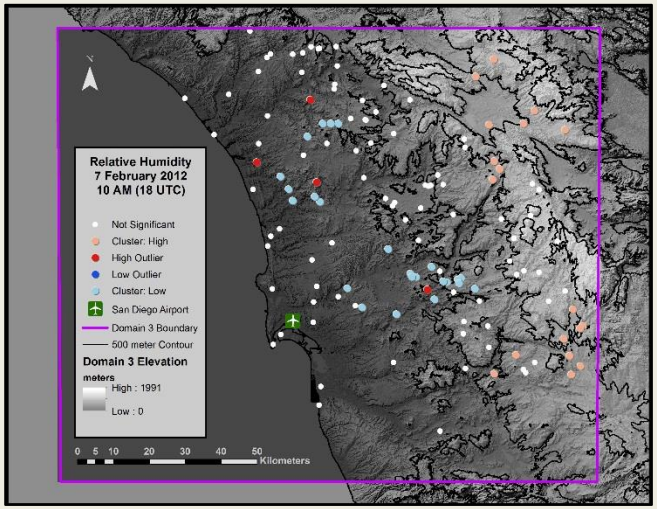


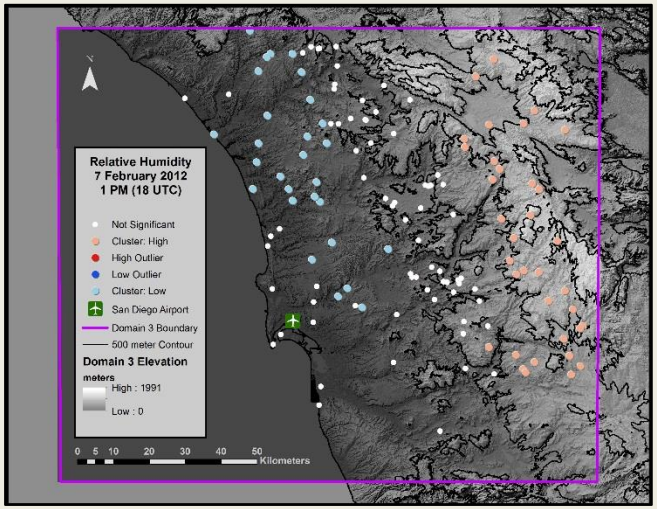


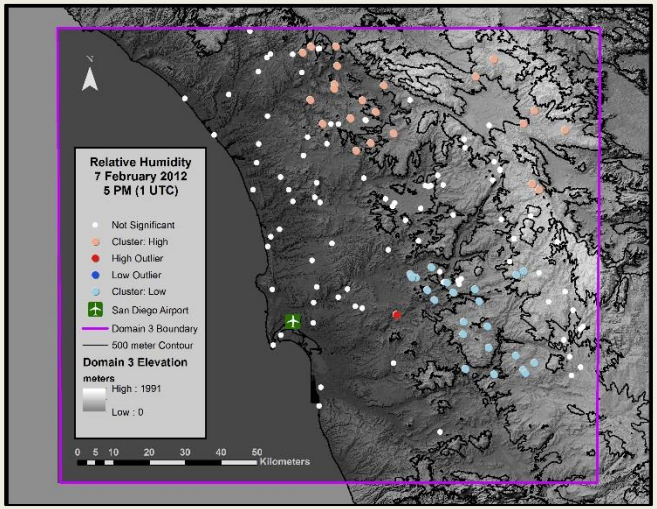


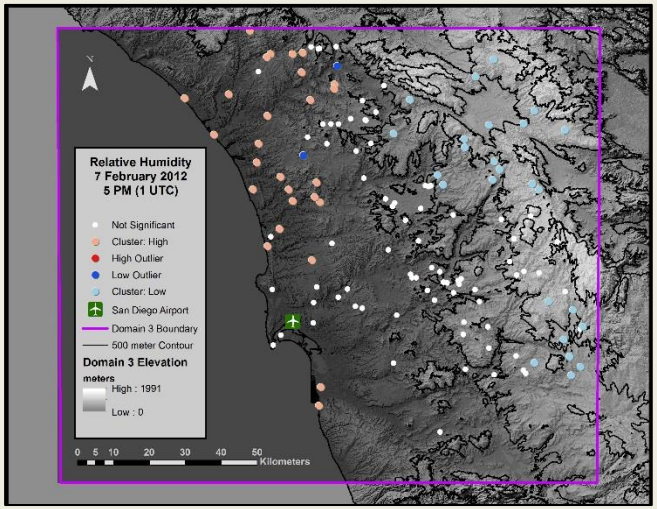


Clustering Analysis of Model Relative Humidity Bias









Used the Hi/Low Cluster Tool of the Spatial Statistics Toolset

Model bias clustering varies both spatially and temporally.

Temperature Model Bias (K)
7 February 2012
Cluster and Outlier analysis
Anselin Local Moran's I

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Conclusions

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GIS is a useful tool for analyzing WRF forecast accuracy.

- Standard WRF analysis packages generally only analyze entire domain.
- GIS gives us information on sub-domain spatial variability.
- With GIS, other spatial datasets can be incorporated into the analysis.

Future analyses using Spatial Statistics tools

- Exploratory Regression
- Geographically Weighted Regression
- Grouping Analysis
- Spatial Autocorrelation (Morans I)